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AN APPROACH TO MAPPING THE DEVELOPMENT OF PROFESSIONAL SKILLS IN A STRUCTURAL ENGINEERING PROGRAMME

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ABSTRACT

Engineers of the future will be presented with complicated, complex problems and their role in the development of sustainable solutions to global problems will become even more critical. Recent literature highlights the need for the development of a set of professional skills in order to address these challenges. These skills include technical, non-technical and attitudinal skills. This paper describes a case study of a whole-of-programme review of teaching and assessment of professional skills in a structural engineering programme. In a systematic process, lecturing staff mapped the modules they teach against a set of professional skills, which were distilled from literature review. The programme map was then analysed to provide insight into the depth to which professional skills are being taught and assessed. This analysis underpinned a review of the teaching of professional skills and led to the identification of both gaps and opportunities to introduce new learning outcomes, teaching activities and assessment techniques.

1 INTRODUCTION

This paper presents the methodology and findings from the second work package of a project which aims to “design our structural engineering programme so that students can develop skills which will enable them to become exemplary structural engineers with a focus on the future of our planet and it’s people.” This work package involves a whole-of-programme review of the teaching and assessment of these skills in a structural engineering programme at TU Dublin.

The aims of this study are to provide insights into the depth to which these skills are currently being taught and assessed in our programme and to identify gaps and opportunities in the programme.

1.1 Skills Development Need

It is clear from the literature that there is little consensus on which skills are most important in an engineering degree programme [1], [2], [3]. This debate has been ongoing since the 1800’s [4]. The role of the engineer is changing and becoming more complex. The societal view of the engineer is broadening from merely being seen as a technical expert. Engineers are dealing with “wicked” problems, and need a range of professional skills in order to solve these wicked problems [5], [6], [7], [8].

Third level institutes are increasingly concerned with ensuring that their students develop skills and attributes which not only prepare them for the world of work, but also better equip them as members of society. Given the climate crisis we are living through, education focus has shifted towards sustainability and the complex problems faced by society. Engineering education has a major role to play here, as it is important that students develop the tools to tackle complex problems, gain awareness of how engineers can affect climate change and attain the skills needed to develop sustainable engineering solutions [9]. It is recognised that graduates need to actively experience, construct and practice in this area in order to build competence [6]. This

challenge can be considered an opportunity for those graduates with the correct balance of strong social, professional and technical skills [10].

The design of the engineering programme at TUDublin is influenced by the accreditation requirements of Engineers Ireland [11] and a new University Strategic Plan [12]. Engineers Ireland is the accrediting body for engineering degree programmes in Ireland and launched a new set of accreditation criteria in January 2021 [11]. The programme outcomes have been broadened with a focus on sustainability, engineering management and teamwork and communication and now include specific aspects of ethical use of technology and data and equality, diversity and inclusion in professional practice.

The University Strategic Plan [12] is based on the concept of three pillars: People, Planet and Partnerships with some parallels to the three pillar model of sustainable development (environmental impact, social impact and economic impact) [13]. The plan commits us to developing responsible global citizens in our students, by facilitating learning and knowledge creation and instilling a sustainability mindset in our students and staff.

Work package 1 that preceded this study involved a review of recent literature alongside chartership requirements of the Institution of Structural Engineers (IStructE) and Engineers Ireland (EI) as well as three seminal consultation and analysis reports on the future skills in the sector. This led to the identification of seven traditional and emerging professional skills presented later in the paper [14].

2 METHODOLOGY

2.1 Programme Structure

The programme assessed in this study is a four year Honours Degree in Structural Engineering. The degree programme has a common entry first year where students learn the fundamentals of a wide range of subjects including civil, mechanical and electrical engineering. In second year, students may choose the civil and structural engineering stream. In third year students specialise further into the civil or structural engineering stream. The analysis of the programme began at Year 2 where the students have selected to follow a career in civil or structural engineering and from the structural engineering stream from Year 3 onward.

A high level overview of the current curriculum is provided in Figure 1. All modules are 5ECTS credit modules unless noted otherwise. Year 1 is shown greyed out as it has not been included in the analysis described in this paper.

2.2 Future Skills

Work package 1 identified a list of 7 professional skills required by future structural engineers. These skills were categorised as follows: **Technical**, which includes Core Technical Skills and Technology and Digitisation, **Non-Technical**, which includes

	Engineering Common Entry	Civil and Structural Engineering Stream	Structural Engineering Stream	
Subject Stream	Year 1	Year 2	Year 3	Year 4
Maths	Mathematics 1	Mathematics 21	Mathematics 31	Mathematics 41
		Mathematics 22	Mathematics 32	
Analysis	Physics	Engineering Analysis 21	Structural Analysis 31	Structural Analysis 41
		Structural Analysis 22	Structural Analysis 32	
Mechanics	Mechanics	Fluid Mechanics	Mechanics of Materials 31	Mechanics of Materials 41
		Mechanics of Materials 21	Mechanics of Materials 32	
		Mechanics of Materials 22		
Professional Development	Professional Practice	Professional Development 2	Professional Development 3	Const. Management and Economics 42
Design Studio	Design Projects	Construction Technology	Design Project 3	Scheme Design 4* 10ECTS CREDITS
Other Subjects	Tech Graphics	Concrete Technology	Design of Steel & Conc 3	Design of Steel & Conc 4
	Chemistry	Surveying	Geotechnical 31	Highway Engineering 42
	Computing		Geotechnical 32	Final Year Project* 15ECTS CREDITS
	Instrumentation		Environmental Engineering	
	ElectroTech			

Fig. 1: Modules within the programme differentiated by stream.

Communication, Management and Engineering Practice and **Attitudes**, which includes Sustainability and Societal skills. The definitions were co-created with structural engineering students and are as follows [14]:

- **Core Technical**: has a strong grounding in mathematics and science within structural engineering. This includes the fundamental principles of structural engineering, material behaviour, engineering equations and problem solving.
- **Technology and Digitisation**: is able to learn and use new technologies and digital advancements in analysis, testing, communication and collaboration.

- **Communication:** can effectively exchange information through a variety of diverse means and with diverse groups in various settings and circumstances.
- **Management:** can manage themselves and others in keeping on track towards an end goal.
- **Engineering Practice:** understands and follows the protocols, processes, rules and regulations of practicing within this field.
- **Sustainability**: has a working knowledge of the impact of design choices on sustainability and targets the reduction of impact on the planet and its natural resources.
- **Societal**: has an understanding of how they can impact society either directly or indirectly, and makes efforts to give back to the community, understanding the inseparability of structure or structural engineering practices and people and place.

2.3 Survey

The skills identified were then used in a survey of lecturing staff to identify where within the current curriculum the students are provided with the opportunity to develop these skills and whether the skills are assessed. 11 of a total of 17 lecturers participated in the study. Lecturers were provided with the definitions and action learning sets developed in Work Package 1 for each skill.

Question 1 asked *"Do you think the student has an opportunity to develop this skill while completing this module?"* The options were *Yes*, *Yes But Limited* and *No*. This question was asked in order to provide insights into what skills we are currently developing in our modules.

Question 2 asked *"If yes, what aspect of the module &/or assessment aids the student to develop this skill?"* This question allowed us to further understand the extent of teaching and assessment of each skill and the relative importance of each skill within each module.

3 RESULTS

The results of the survey were initially compiled in a heat map The opportunity to develop each skill was assessed using a pie chart for each year. Figures 2,4 and 6 show pie charts split between the 7 professional skills based on answers to Question 1. An answer of 'Yes' to Question 1, means that the skill was explicitly taught and assessed. An answer of 'Yes, limited' means that while the skill may have been taught, it was not explicitly assessed. Modules were weighted based on the number of ECTS credits available for the module. When compiling the pie chart for a 5 ECTS module, answers of 'Yes' were given a value of 1, answers of 'Yes, limited' were given a value of 0.5 and answers of 'No' were given a value of 0. For 10 and 15 ECTS credit modules, these values were increased by a factor of 2 and 3 respectively. This gave insights into which skills were being given the most and least opportunities to be developed.

Figures 3,5 and 7 show the corresponding bar charts for each year. These charts were produced to assess the percentage of modules where the opportunity to develop a skill exists versus the percentage of modules where the skill is actually assessed.

3.1 Limitations

It is recognised that not all lecturers responsible for the delivery of modules participated in the study, furthermore the results of the survey rely on the opinion of the lecturer in terms of the extent to which the skill is developed and the categorisation of subject material or activities into skills. The weightings applied to answers in Question 1 are somewhat arbitrary and were chosen by the authors to allow a high level overview of skills development opportunities in the course to take place. The survey did not assess the student's level of performance in these skills or the stages of skill development across various years.

4 DISCUSSION AND CONCLUSIONS

From Figures 2,4 and 6 it is clear to see that the opportunities for development of each skill is quite dispersed and one skill is not totally dominant. This is somewhat surprising given the technical nature of all but one subjects in each year. Below is a brief discussion of the opportunities for development of each skill.

Core Technical: From Figures 2,4 and 6, we can see that the greatest opportunities for skill development lie in Core Technical Skills. From Figures 3,5 and 7 we can see that there is an opportunity to develop Core Technical skills in almost all modules in each year. There is no significant drop off when looking at whether the skill is assessed, as Core Technical skills are a major focus of most modules.

Technology and Digitisation: The opportunity for development of this skill appears in 50% of modules in year 2, 83% of modules in year 3 and 67% of modules in year 4. Unsurprisingly, we can see a large drop off when looking at where the skill is actually assessed. This stems from the fact that technology is merely used as a communication tool in some instances. As an illustration, where a lecturer gave a Yes response to Question 1, in Question 2 they stated, "*The lab exercises include the use of structural analysis software".*

Communication: From Figures 2,4 and 6, we can see that there is an opportunity provided to students to develop Communication skills to some degree in 100% of subjects in 2nd year, 83% in 3rd year and 92% in 4th year. This is somewhat surprising given industry criticism of graduate skills in this area. When we look at where the skill is actually assessed, Communication drops significantly. This is unsurprising as these skills may form part of modules but may not be a major component of assessment.

Management: From Figures 2, 4 and 6, for an engineering degree, there would appear to be consistent opportunities in each year to gain skills in this area. Referring to Figures 3, 5 and 7, these skills are also assessed in 25% of modules in 2nd year and 3rd year and 42% of modules in 4th year.

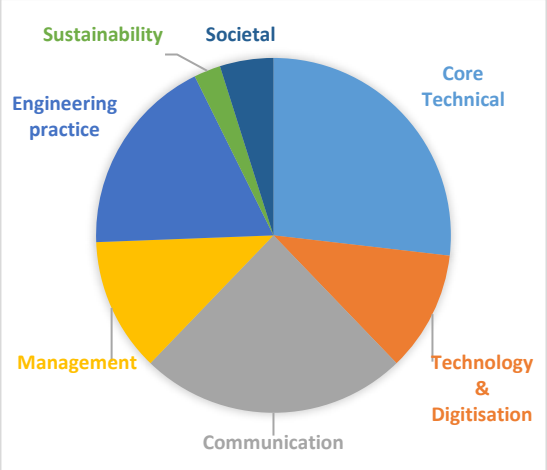

Fig. 2. Year 2 – Opportunities for skills development within modules

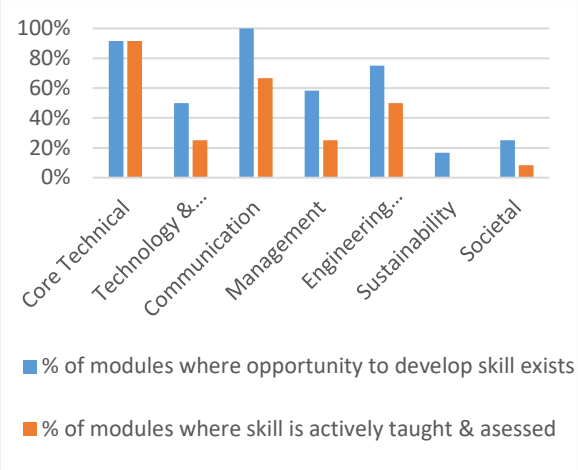

Fig 3. Year 2 - Comparison of opportunity for skills development and current assessment

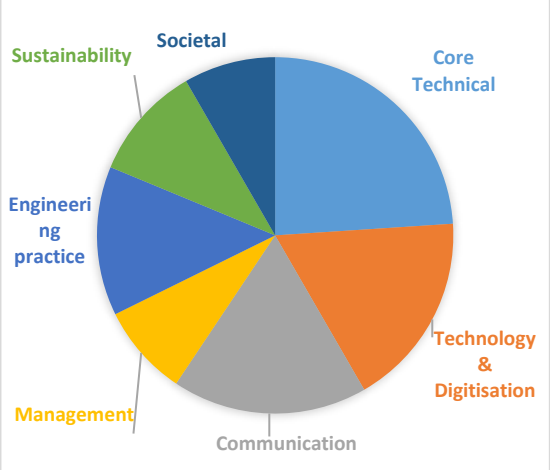

Fig. 4. Year 3 – Opportunities for skills development within modules

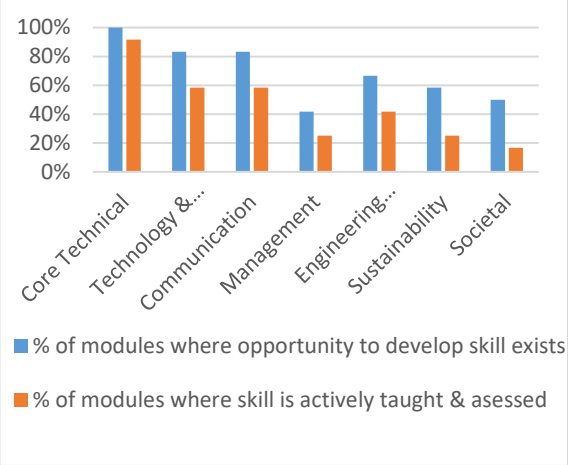

Fig 5. Year 3 - Comparison of opportunity for skills development and current assessment

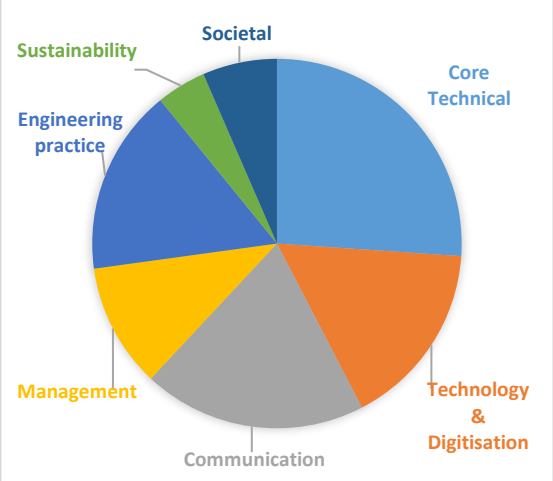

Fig. 6 .Year 4 – Opportunities for skills development within modules

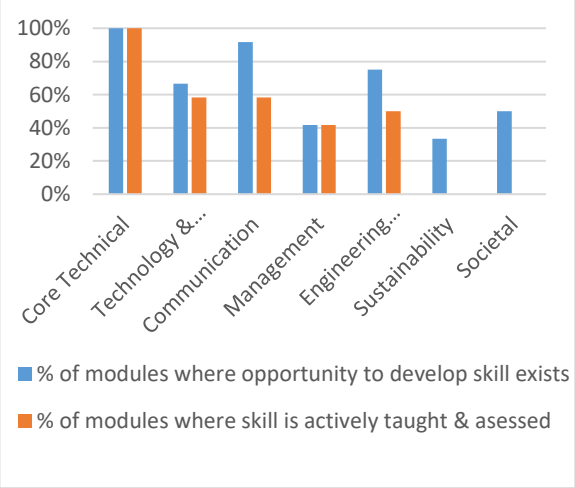

Fig 7. Year 4 - Comparison of opportunity for skills development and current assessment

Engineering Practice: From Figures 2, 4 and 6, the opportunity to develop skills in Engineering practice holds a consistently strong share among other skills. It's relative share drops from 2nd to 3rd year and only partially rebounds in 4th year. This is somewhat surprising as one might assume that opportunities to mimic the work of an engineer would increase through the years.

Sustainability: From Figures 2, 4, and 6, it is clear that while Sustainability forms an active part of the curriculum in 3nd year, it currently forms a very small component in 2nd and 4th year. We can see From Figures 3, 5, and 7 that sustainability is not explicitly assessed in these years.

Societal: From figures 2, 4, and 6 it is clear that while Societal fares slightly better than Sustainability, it is the second last ranked skill in terms of opportunity for development. We can see from Figure 7 that Societal is not explicitly assessed in this year.

When looking at the course overall, there is a good distribution of skills development. When ranking skills development opportunities, the following is the order observed from the survey: 1-Core Technical, 2-Communication, 3-Engineering Practice, 4-Technology and Digitisation, 5-Management, 6-Societal and 7-Sustainability.

A key question that the literature does not answer is, how much opportunity should be provided in an engineering programme to each of these skills? Based on the authors' experience, in the past, this outcome would seem largely appropriate. However, one of our aims is to orientate the views of the student towards the challenges of the future of our planet and it's people. Therefore, it is clear that there is a need to embed more opportunities in the course to develop societal and sustainability skills. A sustainability module has been identified as an immediate requirement as well as further developing a society and sustainability thread throughout each year. Also, the assessment of these skills is a clear priority given the very low survey results in the assessment of these skills, as it is well established that assessment drives learning.

4.1 Future Research

The next stage of this research involves a review of the development of these skills and their threads through the years with reference to the results of Question 2 of this study. This will inform the development of new learning outcomes, teaching activities and assessment techniques in the areas of societal and sustainability skills and will provide a clearer picture as to where the skills need to be integrated into the existing programme.

5 SUMMARY AND ACKNOWLEDGEMENTS

This study was undertaken to create a picture of the content of our current programme in an effort to identify opportunities where there could be a rebalance of the skills that would prepare our structural engineers for the future. What emerges is a reassurance that there is already an acknowledgment of the balance of skills needed, but more

exciting, that there is an openness from the lecturing staff as to the opportunities for skills development, in particular in relation to the concepts of society and sustainability.

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